PRELIMINARY RESEARCH PROPOSAL
SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER
THE ANADROMOUS FISH EVALUATION PROGRAM
2007 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE OF PROJECT

Evaluating Cumulative Ecosystem Response to Habitat Restoration Projects in the Lower Columbia River and Estuary

B. PROJECT LEADERS

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C. STUDY CODE

EST-P-04-04

D. ANTICIPATED DURATION

Entire Study: January 1, 2004 to December 31, 2010

Current Study Period: January 1, 2007 to February 28, 2008

E. DATE OF SUBMISSION

15 August 2006

II. SUMMARY

A. GOALS

The primary goal of this study is to develop and employ science-based methods to quantify cumulative effects[1] on ecosystem function from salmonid habitat restoration in the CRE[2]. A secondary goal is to

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[1] By "cumulative effects" we mean the collective effects on the CRE ecosystem as a result of implementation of multiple habitat restoration projects.

[2] The Columbia River Estuary is defined as the region of the river under tidal influence (i.e., from the mouth to Bonneville Dam at river mile 146).

standardize restoration[3] project monitoring protocols to support the cumulative effects analysis and ensure comparable data sets across multiple restoration monitoring efforts estuary-wide. The management implications are wide-ranging: (1) Decision support for estuarine restoration project prioritization; (2) evaluation of the ecological performance of collective estuarine restoration actions; (3) methods and data for Corps authorities under various Water Resources Development Acts (Sections 206, 306, 536, 1135); (4) protocols to sample listed subyearling fish in estuarine wetlands; (5) database for assessment of relative benefit of investments in tributary versus estuarine wetland habitats; and (6) a collaborative approach for a multi-stakeholder environment.

Measurement of the effectiveness of multiple habitat restoration projects on overall salmon population viability at the scale of the Columbia River estuary is a challenge similar in magnitude to other large scale monitoring efforts, such as those associated with the Colorado River system and the Mississippi River delta. Assessing cumulative ecosystem effects of habitat restoration projects in the CRE may be even more difficult in practice because of the complexity of scale associated with measuring multiple salmon populations with multiple life history strategies in the CRE. Despite the challenges, developing and implementing appropriate indicators and methods is the only way to enable estuary managers to track the effectiveness of their large investments in estuary habitat restoration projects and to improve conservation and restoration measures over time.

The types of estuarine restoration being implemented in the LCRE by the Corps and others include activities to: (1) reconnect backwater channels, sloughs and oxbows and recover estuarine wetlands through dike removal and tide gate replacement; (2) reconnect upland drainages and freshwater inflow through removal of armored channels, culverts, diversions, and other channeling structures; (3) remove intertidal fills and piling fields; (4) allow natural accumulation of large woody debris; (5) place fill material; and, (6) remove armor from shorelines. Such ecological restoration requires that detrimental changes be reversed to a *measurable degree*. However, existing data collection and analytical methods are insufficient to evaluate the cumulative benefits to the ecosystem or salmon populations.

In 2004 (Year 1), the project team developed a set of measurable parameters that on-the-ground restoration managers can reasonably conduct at most if not all restoration project sites, as well as "higher-order" indicators for evaluation of cumulative ecosystem response to habitat restoration projects in the CRE. The 2005 (Year 2) effort implemented assessment methods at two (2) on-the-ground estuarine restoration sites in the CRE as part of the development and testing of indicators and methods. Sampling designs developed for estuary-wide cumulative effects analysis were released in the 2005 annual report. In 2006 (Year 3) the project released the field-tested and revised version of *Monitoring Protocols for Salmon Habitat Restoration Projects in the Lower Columbia River and Estuary* and over 100 copies were requested by individuals with agencies and non-governmental organizations. In addition, post-restoration data were collected at the Year 2 sites creating a data set that encompasses both baseline and post-restoration time frames. This data set was designed to represent the habitat types that have sustained the most loss – marshes and forested wetlands – as well as three of the most typical restoration actions in the estuary: dike breaches, culvert replacements, and tidegate replacements.

B. OBJECTIVES

Overall Multi-Year Study Period (2004-2010)

The overall objectives of this multi-year study are to:

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[3] In this document, the term "restoration" generally refers to any or all of the five fundamental restoration approaches commonly reported in the literature: creation, enhancement, restoration, conservation, and protection (NRC 1992).

1. Develop standard monitoring protocols and methods to prioritize monitoring activities that can be applied to CRE habitat restoration activities for listed salmon.

2. Develop the empirical basis for a cumulative assessment methodology, together with a set of metrics and a conceptual model depicting the cumulative effects of CRE restoration projects on key major ecosystem functions supporting listed salmon.

3. Design and implement field evaluations of the cumulative effects methodologies by applying standard methods, a COE geographic information system (GIS) database[4] of habitat types and land ownership (private, federal, state, local), and sensors or remotely operated technologies to measure through-ecosystem response of the cumulative effects of multiple habitat restoration projects on listed salmon.

4. Develop an adaptive management framework that coordinates and compares the diverse restoration efforts in the CRE, including data management and dissemination, to support decisions by the Corps and others regarding LCRE habitat restoration activities.

Current Annual Study Period (2007)

The objectives of the current annual study are to:

(1) Initiate field data collection at new CRE sites to increase the power of cumulative effects analysis, through a) collaborating with restoration project managers to advise on implementation of the monitoring protocols and b) continue implementing monitoring protocols and field evaluations of cumulative effects indicators at new and existing restoration projects. Evaluate older "accidental" dike breach sites to assess long-term effects, if access is available.

(2) Continue to develop an adaptive management framework, including data management and dissemination, to support decisions by the Corps and others regarding LCRE habitat restoration activities.

(3) Reduce uncertainties regarding role of CRE forested wetlands as salmon habitat through field data collection and evaluation of water quality, channel characteristics, and vegetation.

(4) Develop the CRE GIS database as a platform for modeling to project changes to conditions in the CRE expected with the addition of multiple unique restoration actions.

C. APPROACH

The recommended methods combine state-of-the-science synthesis, innovative indicator development and field-testing, and the creation and implementation of ecosystem-specific monitoring protocols and data management systems to produce biannual estimates of ecosystem and listed-salmon responses to cumulative restoration actions. Future management actions, thus, can be supported by a robust adaptive management decision framework. Theory on cumulative *impact* assessment will be applied in reverse to assess what cumulative *gains* to the ecosystem and selected resources (e.g., listed salmon) are achieved by the multiple restoration projects planned in the CRE. The adaptive management system will be designed

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[4] The GIS database is a collaborative, coordinated effort among multiple parties, including the Columbia River Estuary Study Taskforce, the Lower Columbia River Estuary Partnership, the Pacific Northwest National Laboratory, the University of Washington, and the U.S. Geological Survey.

to incorporate project-specific, salmon-specific, and ecosystem measures and efficiently integrate existing and planned monitoring efforts. Stakeholders, including the Federal Columbia River Power System action agencies, fisheries management agencies, restoration project managers, and the interested public, may share data and reporting systems designed to facilitate communication and partnering, negotiation, and management decision-making.

D. RELEVANCE TO THE UPDATED PROPOSED ACTION

Habitat restoration actions in the lower Columbia River and estuary (LCRE) were included in the 2000 and 2004 Biological Opinions on FCRPS operations and The Action Agencies' draft Implementation Plan for the Updated Proposed Action. The Implementation Plan (USACE et al. 2005; p. 56-57) called for cumulative effects research, as follows:

			S	A	U
Thom et al. 2003-2009 *Evaluating the Cumulative Ecosystem response to Restoration Projects in the Columbia River Estuary* (Corps).	Initiate a research project to develop a framework and methodology to measure and evaluate the cumulative effects of habitat restoration actions within the lower Columbia River and estuary. Additionally, develop standard protocols for key monitoring attributes of estuary ecosystem structures, processes, and functions to be implemented at both restoration and reference sites. These protocols have (in draft format) been coordinated throughout the region through LCREP and CREST audiences. The Action Agencies intend to use this multi-year research effort to establish scientific capability to assess whether habitat restoration is having a		X	X	

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2005 — 2007 Implementation Plan

Project/Action & Agency (Estuary RM&E)	2005-2007 Objective/Deliverable	S	A	U
	measurable, cumulative effect on the lower river and estuary, and ultimately contributing to the recovery of ESA listed salmonids in the Columbia Basin.			

Other closely related monitoring projects in the CRE include "Estuarine Habitat and Juvenile Salmon – Current and Historical Linkages" by NOAA Fisheries and others (Corps EST-P-02-02), "Habitat Monitoring in the Lower Columbia River and Estuary" by the Lower Columbia River Estuary Partnership (BPA 2003-007-00), and "Research, Monitoring, and Evaluation Plan for the Columbia River Estuary and Plume" by the Action Agencies and others (BPA 2002-077-00).

III. PROJECT DESCRIPTION

A. BACKGROUND

Under Congressional authorities in various Water Resource Development Acts, the Corps of Engineers and others are working to restore estuarine habitats in the Columbia River Estuary. The number of restoration projects being planned and implemented in the CRE has increased in recent years through the coordinated efforts of state, federal, and local organizations. For example, the types of estuarine restoration being implemented in the LCRE by the Corps and others include activities to: (1) reconnect backwater channels, sloughs and oxbows and recover estuarine wetlands through dike removal and tide gate replacement; (2) reconnect upland drainages and freshwater inflow through removal of armored channels, culverts, diversions, and other channeling structures; (3) remove intertidal fills and piling fields; (4) allow natural accumulation of large woody debris; (5) place dredged material; and, (6) remove armor from shorelines. The vision is to improve CRE ecosystem functionality through habitat restoration efforts to aid in rebuilding listed salmon stocks in the Columbia Basin.

As the salmon habitat restoration effort grows, projects being implemented will require some level of monitoring and evaluation to determine their effectiveness. It will not, however, be practical to intensively monitor the results of every project. Ecological restoration at this scale requires that detrimental changes be reversed to a _measurable degree_. Therefore, methods must be established to prioritize and manage limited monitoring budgets while determining whether the proposed restoration actions will have a net cumulative benefit to CRE ecosystem health and functionality. In addition, data from numerous restoration monitoring efforts should be as comparable as possible to aid decision-makers as they learn from the collective project-specific monitoring data. Standardized monitoring protocols are necessary to compare restoration effectiveness through time at a given project site and through space among multiple projects. Focused, prioritized, and standardized monitoring at the project scale will support monitoring and evaluations at the estuary scale that will ultimately help to measure the success of the CRE salmon habitat restoration.

Although it is relatively straightforward to measure the area of habitat restored, it is difficult to assess the cumulative effects of individual restoration projects on ecosystem function. Currently, a formal method for quantifying whether restoration of habitats will have a measurable effect on the health and functionality of the ecosystem or on the viability of salmon populations does not exist in the literature. Small projects may result in local improvements, which are confined to a relatively short distance from the restoration site. Many small projects may only improve conditions within a small area, and not have any significant effect on the larger ecosystem. In contrast, a mix of large and small projects, placed strategically within the system, and containing the appropriate mix of habitats, and managed in a way to maximize success, may provide highly significant improvements. The availability of land in the CRE for habitat restoration, however, will be an important factor affecting the size of projects to be implemented. Implementation of the methodology developed in this study will likely be affected by the types and sizes of potential projects and, therefore, the methodology must allow for objectively incorporating this variable. Most importantly, restoration actions in the CRE represent a unique opportunity to develop and employ science-based, defensible methods to evaluate the potential cumulative gains in restored ecosystem function provided by a suite of restoration projects in the system.

Accounting for the total effect of multiple restoration actions on the functioning of the system is both one of the most important and challenging topics in restoration science. In theory, it is assumed that any improvement to a component (e.g., enhancement of a selected habitat attribute; Shreffler and Thom 1993) will contribute to overall ecosystem improvement. However, the size, amount, number of projects, types of projects, etc. that will have the greatest benefit varies with the ecosystem. In a situation where the state of the system has been altered, such as in the CRE, knowing how many and what type, and the location of

projects that result in a reversal of degradation and a measurable switch back to a former (and less disturbed) system state would help guide restoration programs and justify the expenditures of funds directed toward restoration. The development of methods to detect and assess the cumulative net improvement toward a former system state is the focus of this research. Relevant to the proposed research, we paraphrase the definitions of cumulative impacts and cumulative effects in Leibowitz et al. (1992) as follows:

- *Cumulative restoration impacts* are the net sum of all changes in selected habitat metrics of all restoration projects occurring over time and space, including those in the foreseeable future of the development of these projects.

- *Cumulative restoration effects* are the net change in ecosystem-wide metrics and ecosystem state resulting from cumulative restoration impacts.

The challenge of balancing the need for coastal economic development with enhancement of coastal ecosystems is among the top priorities for coastal planners and researchers this century (Thom et al. 2005). In this context, we introduced the concept of "*net ecosystem improvement*", which is defined as "following development, there is an increase in the size and natural functions of an ecosystem or natural components of the ecosystem" (Thom et al., 2005). We argue that this concept is critical to meeting sustainability of coastal systems as defined by the World Commission on Environment and Development (1987). The present study will provide much needed data and guidance on the effects of habitat restoration intended ameliorate development in the Columbia River.

This project is addressing the above issues and providing information that can be used to make management decisions primarily regarding cumulative effects of mitigation and estuarine restoration that are designed to enhance ecological functions benefiting the estuarine ecosystem and its juvenile salmon inhabitants. The work is intended to provide means to assess and quantify the cumulative improvements associated with restoration projects and to lay the foundation for the evaluation of the effectiveness of the restoration activities undertaken. Thus, this project is intended to examine the effects of habitat restoration in the CRE in a comprehensive, ecosystem basis. As such, the central premises guiding this work are as follows:

- Standardization of monitoring methods will result in comparable data sets

- Monitoring efforts can be prioritized and designed strategically while maintaining statistical robustness

- Cumulative effects on the CRE ecosystem designed to benefit salmon must be viewed at a landscape scale

- A conceptual model[5] of the CRE ecosystem, including the food web, provides organization and focus to the research and assessment

- Key attributes indicating ecosystem response to restoration will be assessed and used

- A framework can be developed and applied to assess the cumulative effects for all restoration actions

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[5] This project will consolidate existing conceptual models for the CRE (Bottom et al. 2001; Thom et al. 2001).

- An adaptive management system based on project and ecosystem monitoring data will aid decision-makers implementing salmon habitat restoration in the CRE

The project has completed the first of four objectives and made progress on the remaining three, as detailed here, in chronological order: In the first year of this project (FY04), the cumulative effects project team reviewed applicable monitoring protocols (Task 1.1), conducted outreach (Task 1.2), and participated in a forum (Task 1.3) with restoration project managers and the Estuary Partnership to discuss monitoring needs relevant to tracking the success of restoration projects. Interfacing this effort with its analysis of the state-of-the-science via existing restoration literature, the team produced a set of draft monitoring recommendations – supported by many restoration project managers – that is to serve as a template for ongoing and future effectiveness monitoring for the region. This was a critical component of the draft monitoring manual (Task 1.4) a Year 1 deliverable by the project. Restoration project managers will be able to apply this set of measurable parameters at most, if not all, restoration project sites. In Year 2 (FY05) the project team continued to develop and test indicators, methods and a sampling design for estuary-wide cumulative effects analysis. This tiered approach incorporates a) a short list of minimum indicators (and appropriate protocols) for project-specific implementation monitoring, the results of which can be rolled up into estuary-wide analyses, and b) ecosystem indicators that require intensive monitoring, which can be evaluated at specific study sites in order to limit overall monitoring program costs. The year 1 literature review further demonstrated the need for such research to increase the scientific defensibility of restoration, and has uncovered few comparable efforts in restoration science (e.g., Steyer et al. 2003).

Indicators and cumulative effects methodologies from disciplines including forestry, fisheries, ocean sciences, wetlands, physics (complex systems), and watershed sciences were assessed during the year 1 literature review for their applicability to the CRE (Task 2.1). The potential indicators evaluated included organic matter production and flux; nutrient processing; sedimentation; macroinvertebrate production; food web/stable isotope method; salmon habitat usage; salmon habitat opportunity/connectivity; and bioenergetic modeling (Task 2.2). This review formed the basis of the sampling design for field monitoring that was developed and implemented in Year 2. The results of 2005 field studies analyzed in Year 3 (FY06) were used to validate and improve the monitoring protocols, which were released in a revised draft in April of 2006 (Task 1.5). Over 100 copies of the field-tested and revised version of *Monitoring Protocols for Salmon Habitat Restoration Projects in the Lower Columbia River and Estuary* were requested by individuals with agencies and non-governmental organizations. *This completed the first of the four project objectives.* A manuscript combining the literature review (Year 1) and cumulative effects methodology (Year 2-3) is in preparation for submission to a peer-reviewed journal. An oral presentation at the National Conference on Ecosystem Restoration (2004), and poster presentations at Pacific Estuarine Research Society (2005, 2006); Society of Wetland Scientists/Society for Ecological Restoration Northwest (2006); and the Conference on Research, Monitoring, and Restoration in the Lower Columbia River, Estuary and Nearshore Ocean (2006); were made to communicate the project outcomes to date to the interested technical and management community. A statistical sampling design for cumulative effects analysis has been developed and released in the 2005 Annual Report (Task 2.1) and a subset of metrics is being developed for cumulative effects analyses (Task 2.2). This sampling design and meta-analysis will require field sampling and data collection from additional sites to achieve adequate power (Objective 3 in overall study design below; and Objective 1 for FY07 studies cited above).

B. TASKS AND METHODS

The tasks and associated methods below are organized by study objective.

<u>Objective 1</u>. Develop standard monitoring protocols that can be applied to CRE habitat restoration activities for listed salmon.

Development of standard protocols serves a number of needs relative to the cumulative effects program and other related programs in the CRE. First, the protocols establish a standard set of methods and metrics that should be utilized in the evaluation of restoration projects conducted within the system. By having a standard set of methods and metrics, the data acquired is comparable among projects, and allows a systematic assessment of the effects of each of these projects. Second, the database developed allows for broader assessments of system-wide changes (i.e., improvements) in habitats and functions supportive of salmonid populations. Third, programs funded by other entities can use information generated by these systematic studies to understand the rates and patterns of development of various habitat types, and to refine the metrics required to assess their performance. Fourth, the data set provides the critical element to an adaptive management framework. Systematic data taken at a growing number of sites, when evaluated annually by planners and managers, is extremely valuable in determining whether changes in the projects or programs are needed to better meet project and program goals.

Task 1.1: Review literature for monitoring and evaluation of estuarine habitat restoration projects and identify techniques and protocols applicable to the CRE.

There is a large body of literature available regarding monitoring and evaluation for estuarine habitat restoration projects (e.g., Simenstad et al. 1991; National Research Council 2001; Busch and Trexler 2003). This literature will serve as a basis to develop standard monitoring protocols and prioritize monitoring efforts. Restoration projects in the CRE typically consist of reconnecting historical water exchange pathways with the goal of enhancing access of juvenile fish to rearing habitats. Such changes to the physical attributes of a system, and the resultant alteration of ecological functioning, are time-dependent processes. The cumulative effect of restoration activities thus has a temporal aspect that must be adequately addressed with a standardized monitoring program.

The ideal sampling design has 1) Impact, Reference, and Control systems[6]; 2) replicated sampling sites within each system; and 3) a suite of state and target monitoring variables during pre-and post- restoration periods within each system. The Control system should be as similar as possible to the Impact system without undergoing the restoration process. The Reference system is intended to be the model trajectory for the restoration process. It is recognized that this complete design will not be feasible for most studies. We must therefore prioritize the monitoring effort (i.e., whether Reference and/or Control sites are both necessary) to maximize information gain and especially to facilitate comparisons between studies. At the very minimum, it is important to conduct pre-restoration sampling at the Impact site, as only then can changes to the system be evaluated.

For the development of protocols, restoration activities will be divided into categories according to the particular types of data monitoring required. For example, one project may concentrate on the effect of dike breaching on changes in opportunity for juvenile salmon, and another may monitor alterations in prey production. While the response variable (e.g., salmon abundance or prey production) may differ between different categories of activities, measures of such state variables as tidal height and temperature will be important and common measures to a wide range

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[6] The Impact system is the site being restored; the Reference system is a nearby site that is in a desired state; and the Control system is an adjacent, similar site that is not being restored. The applicability of control and/or reference sites depends on the restoration project and its goals.

of categories. These state variables can link studies with disparate response variables, and thus allow a synthesis of the varied restoration activities over landscape spatial scales and decadal temporal scales. This task will identify the significance of each monitoring parameter, and where automated data logging instrumentation can best be employed. A comprehensive description of metrics and attributes will be compiled from sources including the literature and expert opinions. The standardized sampling protocols developed will include all necessary features such as sampling frequency, measurement units, and procedures. A statistician will be consulted in all matters pertaining to experimental design, inference, and prediction.

The monitoring protocols for Objective 1 will include some of the performance indicators and attributes being developed for the CRE portion of the federal RME plan for BiOp implementation. The monitoring protocols in the federal RME plan, however, will be somewhat general in nature, whereas the monitoring protocols arising from Objective 1 in this study are intended to be detailed and specific. As mentioned below under "Other Research", the two efforts will be coordinated.

Task 1.2: Review ongoing monitoring and research activities, and integrate this information with the results from Task 1.1 to prepare for Tasks 1.3, 1.4, and 1.5.

Monitoring and research activities are currently underway in the CRE as part of Corps and other programs. Information and experience from these projects will be applicable to the monitoring protocols to be developed under Objective 1.

Task 1.3: Conduct a meeting to communicate and receive input from local and regional organizations involved or interested in monitoring habitat restoration projects in the CRE.

To facilitate the fastest collection of existing protocols in use or planned for use in the CRE, as well as expert opinion, a one-day meeting will be held for those involved in monitoring efforts on the CRE and other scientists involved in protocol development. As a result, this project will be introduced to local restoration planners as early as possible in their planning processes, which will increase their ability to put the anticipated product of this task, the manual of procedures, to use in a timely manner. A second meeting may be held to introduce the manual to local and regional restoration managers and planners in Year 3.

Task 1.4: Develop a manual that outlines standard protocols to design and prioritize restoration projects in the CRE.

A draft standard protocol manual will be developed in FY04. It should be revised and finalized based on the material developed in Tasks 1.1 and 1.2. It will be a stand-alone document in addition to being included in the annual report for this study. The manual will include statistical considerations in the design of monitoring efforts. Local entities performing on-the-ground monitoring work will have substantive involvement during manual development via project meetings at the local level, the involvement of CREST on the project team, and cooperation and coordination with the Lower Columbia River Estuary Partnership. The Corps of Engineers will apply the results of this effort to ongoing and planned restoration work (e.g., the Brownsmeade and the Crims Is. projects). Since it is important and well recognized that monitoring results must be comparable within and across individual projects on an estuary-wide basis, we anticipate that entities monitoring restoration projects will find the manual to be beneficial and thus use it.

Task 1.5: Identify methodological deficiencies and perform focused field evaluations of new or revised techniques as necessary.

During development of the monitoring protocols manual, it is possible that there will be uncertainty in choice or availability of particular methods to meet specific needs. This situation would necessitate the need to develop or customize a particular monitoring technique. Some monitoring protocols may be general in nature or adapted from another estuary and, thus, require directed research to be applied specifically to the CRE. In another case, a new technique may become available that would be appropriate to evaluate for CRE monitoring. For example, in Year 3, total dissolved gas will be assessed as a potential indicator.[7] This task addresses fieldwork that may be necessary to ensure that the best available monitoring methods are applied.

<u>Objective 2</u>. Develop the empirical basis for a cumulative assessment methodology, together with a set of metrics and a conceptual framework depicting the cumulative effects of CRE restoration projects on key major ecosystem functions supporting listed salmon.

Task 2.1: Review any new (2005) literature, evaluate methods applied previously in other systems, and assess models employed for the purpose of cumulative ecosystem effects.

Key major ecosystem functions to be considered are the production and flux of marsh macrodetritus, sediment trapping, nutrient processing, floodwater storage, and macroinvertebrate production. The relative roles of macro- and micro-detritus in the CRE ecosystem will be investigated.

Task 2.2: Based on any new information, revise the set of metrics for a cumulative assessment methodology developed in FY04.

A set of draft metrics will be developed from published information and discussions with knowledgeable individuals. At this point, the understanding of cumulative effects generally is applied to cumulative impact assessment of disturbances to the ecosystem or resources. We will apply this theory in reverse to assess what cumulative gains to the ecosystem and selected resources are gained by multiple restoration projects. Our bases for judging cumulative effects are two: 1) what are the quantifiable changes in selected system metrics with each project. This is a straightforward study based on highly relevant and well-founded metrics and indicators; and, 2) at what point can incremental restoration be detected by a response variable in the CRE ecosystem. The answers to these questions are directly applicable to addressing the amount of restoration required to move the ecosystem toward goals established for restoration of salmonids and other species (e.g., murrelet), and what types of projects produce the best gain in ecosystem function according to the metrics chosen. This statistically sound approach will lead directly to project design considerations. It is intended to illustrate whether restoration projects are making a difference in the health of the ecosystem and to selected ecosystem components.

Task 2.3: Develop a conceptual ecosystem model and apply it in a conceptual framework for predicting the cumulative effects of individual restoration projects on key major ecosystem functions supporting listed salmon.

A conceptual ecosystem model will be developed by consolidating existing models, such as Bottom et al. (2001) and Thom et al. (2001). This model will be applied to develop a framework will be quantifiable using empirical data employing landscape ecology principles. The

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[7] Recent concerns regarding the potential effects of total dissolved gas downstream of Bonneville Dam led the COE to request that this indicator be tested in the CRE.

framework will include existing models of the food web, circulation patterns, and water property dynamics. For example, the research proposed will establish the links between landscape features (e.g., size, connectedness, morphology, habitat diversity) and function (e.g., organic matter production and flow, organic matter fate, effects of restoration on the food web pathways). These links will allow calculation of the rates and amounts for the realized functions with the baseline conditions of the larger ecosystem. We will include an understanding of existing concentrations of organic matter, the dynamics of tidal flux in and out of restored systems, etc. The framework will allow us to predict which projects individually or in aggregate, e.g., those with a certain size or location or shape, will provide detectable functions within the larger ecosystem.

Task 2.4: Summarize the cumulative effects methodology.

A summary will be prepared for the metrics, protocols, and sampling design to assess cumulative effects and will include methods to analyze data. This will result in improved monitoring of future projects. In addition, the methods summary will provide guidance for existing projects by specifying how new project information can be fed into the adaptive management program described below. We will evaluate and prescribe the approach to determine the appropriate sampling design for monitoring cumulative effects. This includes ecosystem stratification, sample site selection, replication, sample unit size, etc. The sampling design work will be conducted with guidance of a statistician familiar with the system and the intent of this project. All of this information will be included in an annual project report (see Deliverables and Schedule).

Task 2.5: Field-test cumulative assessment method(s).

Field research will be necessary to develop cumulative assessment methods in the CRE because this topic matter is currently not well understood. The metrics and approach developed in Task 2.4 will be evaluated using data collection and analysis at selected field sites within the estuary. We plan to establish sampling sites in existing restored sites and systematically sample various metrics. Some important functions would include nutrient processing (indicates ability to improve water quality), marsh accretion (indicates sediment trapping), rate of peat development (indicates increasing habitat stability), and marsh-channel morphology (indicates relation of channel velocity gradients to ecological processes). Feasibility testing of evolving technologies such as acoustic telemetry will also be conducted in shallow-water estuarine habitats. Thus, Task 2.5 is focused on any field research necessary to develop the cumulative effects monitoring protocols, whereas Objective 3 involves regular monitoring for the cumulative effects of restoration.

Objective 3. Design and implement field evaluations of the cumulative effects methodologies by applying standard methods, a geographic information system (GIS) database of habitat types and land ownership (private, federal, state, local), and sensors or remotely operated technologies to measure through-ecosystem response of the cumulative effects of multiple habitat restoration projects on listed salmon.

Task 3.1: Design and implement pilot field evaluations directed at measuring cumulative effects.

This task will provide baseline data on the cumulative effects of habitat restoration actions in the CRE for documenting BiOp implementation in 2005. Building on work accomplished for Objective 1, the field studies in Objective 3 would involve a selected subset of restoration projects and associated monitoring programs to assess their effects. The monitoring metrics to be

developed under Objective 1 will be evaluated in Task 3.1. The metrics we presently see as important to the ecosystem are the production of detritus, the ability of juvenile salmonids to benefit from the restoration projects, and the additional benefits of restored systems for functions such as flood storage and sediment trapping. Hence the metrics that likely will be employed will assess the effects of restoration projects on organic matter flux (especially marsh macrodetritus) into the larger estuary system. Potential indicators of this flux will be net areal primary productivity (the source term), and organic matter in sediments and surface water outside the restored marsh and swamp systems. Most importantly, we will consider the cumulative increase in access to productive marsh channel habitats by juvenile salmon. Assessment methodologies that can more easily be done remotely or with instrumentation will be evaluated in order to more comprehensively and cost-effectively assess performance of these systems. This project will help define at what scales we can detect ecological changes due to habitat restoration projects.

Task 3.2: Develop a COE geographic information system (GIS) database of habitat types and land ownership (private, federal, state, local) in coordination and collaboration with other ongoing GIS work.

To plan and prioritize COE restoration projects, a GIS database is necessary. This database will include layers for property ownership, land use, and other physical features. This new GIS effort will be coordinated with ongoing efforts to develop GIS platforms at the Columbia River Estuary Study Taskforce, the Lower Columbia River Estuary Partnership, the University of Washington, and the U.S. Geological Survey. GIS provides a comprehensive analysis and planning tool that integrates with modeling. Existing hydrological models will be reviewed in a needs assessment for their potential to contribute to evaluating the cumulative effects of restoration on wetted estuarine habitat area and flood storage capacity.

Task 3.3: As in Task 1.2, coordinate and communicate with organizations involved in monitoring habitat restoration projects in the CRE to implement standard methods.

This project will seek involvement at the local, on-the-ground level in the CRE. Coordination with organizations involved in monitoring habitat restoration projects in the CRE will maximize efficiency in the implementation of field evaluations of cumulative effects. These entities may be able to contribute data to the cumulative effects monitoring effort in ways to be determined through Task 2 of this project. We will present the results of our work each year to interested parties and invite restoration project managers to share data. We will also produce annual reports of the research findings. We will present results at annual meetings of regional societies such as the Pacific Estuarine Research Society, and the American Fisheries Society, as appropriate. Our intent is to communicate the results of the work frequently so that managers, decision makers, and those directly involved in funding and constructing restoration projects can apply the results in a timely manner.

Objective 4. Develop an adaptive management system, including data management and dissemination protocols, to support decisions by the Corps of Engineers and others regarding CRE habitat restoration activities intended to increase population levels of listed salmon.

The following five subtasks will meet the fourth objective by synthesizing the outcomes of Objectives 1-3 as follows: information gathered from individual restoration project monitoring according to the protocols developed in Objective 1, will be synthesized with cumulative effects data gathered in Objective 3 according to the protocols developed in Objective 2, in order to derive recommended management actions for existing and proposed restoration projects in the CRE.

Task 4.1: Prioritize COE monitoring activities for adaptive management at the landscape scale.

This task is related to Task 1.3. A system such as that developed in the Estuarine Habitat Assessment Protocol (Simenstad et al. 1991), which classifies projects for minimum, recommended and preferred monitoring approaches, will be developed for the CRE, drawing on published methods as well as information specific to the CRE.

Task 4.2: Develop guidelines for data production for individual restoration project monitoring.

Detailed procedures including, for example, appropriate units and appropriate spreadsheet formats, will be developed and disseminated to local restoration project managers to ensure the standardization of data and make landscape-level synthesis, analysis and evaluation possible.

Task 4.3: Provide specifications for a web-based database for CRE monitoring data that the COE could develop and include on its proposed website for CRE Habitat Restoration.

A website and linked database will be specified for monitoring data generated by the cumulative effects research. The intent is to provide public access to the results from this project and the on-the-ground monitoring projects funded by the COE. This will result in a widely available database allowing agencies and stakeholders alike to access the information. The website and database should be designed to link to other sites maintained by restoration teams working on the CRE to facilitate access to all current data on the estuary for decision support. This is expected to significantly enhance management, communications, and negotiation processes.

Task 4.4: Develop a landscape-scale adaptive management system for CRE restoration projects.

The adaptive management system, as described in Thom (2000), will detail the analyses of data from the CRE restoration database and cumulative effects monitoring that will be required to assess project results against performance standards for listed salmon and required habitats. It will provide a decision framework to produce management recommendations if performance standards for the cumulative effects of CRE restoration projects on listed salmon are not met. It will be consistent with the conceptual models currently developed for the CRE (Bottom et al. 2001; Thom et al. 2001). The adaptive management plan will take its goal from the 2000 FCRPS BiOp: that habitat restoration in the CRE contribute to the increased annual population growth of listed Columbia River Basin salmon species. The adaptive management plan will provide an integrative decision framework to enable managers to incorporate the results of the status monitoring and action effectiveness research described in the Estuary and Ocean Subgroup Research, Monitoring and Evaluation Plan that is currently under development. We recognize, however, that the CRE is part of a larger, interconnected landscape supporting salmon in the Columbia Basin. Actions or conditions outside the CRE, e.g., ocean productivity, hatchery practices, will affect ecological conditions inside the CRE. Thus, elements beyond the CRE must be considered to provide context for the landscape-scale adaptive management system for CRE restoration projects.

Task 4.5: Coordinate and communicate with organizations involved in monitoring habitat restoration projects in the CRE to disseminate data as needed for management decision making.

Communication will be essential to ensure that the database and architecture for a decision framework are available to organizations monitoring COE and other estuary restoration actions. Communication will be coordinated with the planned outreach to local restoration managers described in Tasks 1.3 and 3.2 above.

C. FACILITIES AND EQUIPMENT

No unusual facilities or equipment are anticipated at this time.

D. IMPACTS

Test Fish: An ESA Incidental Take permit and State of Oregon and Washington collection permits will be required to sample fish. Test fish may be sampled in year 4.

Other Research: We plan to coordinate closely to assure that sampling efforts are complementary. We also will coordinate with other researchers to avoid conflicts. See Tasks 1.2 and 3.2. In addition, this project is consistent with Action Effectiveness Research (AER) prescribed for the CRE in the federal RME plan for BiOp implementation. We will coordinate with others researching the effectiveness of individual restoration actions, i.e., projects. Furthermore, this AER work proposed here complements other studies performing Status Monitoring for federal RME, such as NOAA's monitoring efforts for the COE and the Estuary Partnership's habitat monitoring for the BPA.

Hydropower Project: Not applicable.

E. PROGRESS ON THE OBJECTIVES AND TASKS

This is a multi-year project that started in FY04. The following table summarizes progress to date for the tasks under each objective and indicates level of effort planned for FY07 (Year 4). The tasks are described in detail in the detailed project proposal (Section III.B). Status is projected as of November 30, 2006. In summary, to date, this study has (1) identified minimum and "higher-order" indicators and designed a weight of evidence approach for cumulative effects evaluation (2004 annual report); (2) summarized juvenile salmonid usage of LCRE habitats to support method development (2004 annual report); (3) released the field-tested and revised version of *Monitoring Protocols for Salmon Habitat Restoration Projects in the Lower Columbia River and Estuary* (over 100 copies were requested by individuals with agencies and non-governmental organizations) (see 2005 annual report); (4) initiated sampling of basic and higher order metrics to evaluate their effectiveness and feasibility for analyses of estuary-wide cumulative effects (2005 annual report); (5) Developed a statistical sampling design for estuary-wide cumulative effects analysis (2005 annual report); (6) involved multiple stakeholders in a monitoring protocol review and testing process using field testing at restoration sites in the LCRE; and (7) Created a data set that encompasses both baseline and post-restoration time frames for 2 restoration and 2 corresponding reference sites; this was designed to represent the habitat types that have sustained the most loss – marshes and forested wetlands – as well as three of the most typical restoration actions in the estuary: dike breaches, culvert replacements, and tidegate replacements.

Objective	Task	Status
1. Standard monitoring protocols	1.1: Review literature	Done; revise as new information becomes available
	1.2: Review ongoing monitoring activities	Done; revise as new information becomes available
	1.3: Conduct an information exchange meeting	Done; revise as new information becomes available
	1.4: Develop a protocols manual	Done; revised draft issued in

Objective	Task	Status
		FY06
	1.5: Identify deficiencies and perform focused field evaluations	Done; revise as stakeholder comments become available
2. Develop the empirical basis for a cumulative assessment methodology	2.1: Review literature	Done; revise as new information becomes available
	2.2: Revise metrics for a cumulative assessment	Done; revise as new information becomes available
	2.3: Develop conceptual ecosystem model and cumulative effects framework	Done; revise as new information becomes available
	2.4: Summarize the proposed cumulative effects methodology	Done; manuscript in preparation
	2.5: Field-test cumulative assessment method(s)	Started; primary in FY07
3. Design and implement pilot field evaluations of the cumulative effects of restoration projects	3.1: Design and implement pilot field evaluations	Started; primary in FY07
	3.2: Establish GIS database	Revision and development is primary in FY07
	3.3: Coordinate and communicate	Started; primary task in FY07
4. Develop an adaptive management system	4.1: Prioritize COE monitoring activities	Started; primary task in FY07
	4.2: Develop guidelines for data production	Started; primary in FY07
	4.3: Provide specifications for a web-based database	Started; primary in FY07
	4.4: Develop a landscape-scale adaptive management system	Started; primary in FY07
	4.5: Coordinate and communicate to disseminate data	Started; primary in FY07

F. SCHEDULE AND DELIVERABLES

To date, the project is meeting its schedule of tasks and deliverables. We anticipate that this study will last seven years. In general, Year 1 and Year 2 entailed the development of methods and tools that the Corps of Engineers and others can apply immediately to restoration monitoring efforts. Years 3-7 will finalize the monitoring protocols including methods and evaluation of cumulative effects of restoration projects. The level of effort anticipated for each study-year by objective is depicted in the following table. (Key: dark shade = high level of effort; intermediate shade = medium effort; and light shade = low effort.)

Objective	2004	2005	2006	2007	2008	2009	2010
Objective 1: Project monitoring protocols							

Objective 2: Cumulative effects methods							
Objective 3: Field evaluations							
Objective 4: Adaptive management system							

The overall intent is to annually provide information on CRE habitat restoration monitoring and evaluation to decision-makers. Understand, however, that any cumulative effects of habitat restoration are not likely to be evident in the short-term. Annual reports will be delivered documenting the work to-date and providing feedback and recommendations to decision-makers on the CRE habitat restoration effort. A generic format for the annual report will be: 1) what was done this year; 2) what was learned; 3) actions planned for next year based on experience to-date; and 4) summary of progress and its management implications. We plan to publish much of the material developed in this study in the peer-reviewed literature. The following table shows the annual schedule and deliverables, along with management implications, for each year.

Year	Deliverables	Management Application
1 2004	Annual report with draft monitoring manual, including site-specific monitoring protocols, cumulative effects literature review, and monitoring program strategy. Paper suitable for publication: "A review of cumulative effects research methods in ecological restoration"	Comparable data sets and prioritized monitoring
2 2005	Annual report with results of any field research for site-specific monitoring protocols and further development of cumulative effects methodology. Paper suitable for publication: "Cumulative effects assessment strategy and adaptive management plan for the Columbia River estuary"	Method to assess the success of habitat restoration efforts at the ecosystem level in the CRE. Methods, information, and recommendations for restoration decision-makers
3 2006	Annual report with final manual for monitoring protocols and field research. Paper suitable for publication: "Techniques for monitoring restoration projects in the Columbia River estuary"	Ditto
4 2007	Annual report of field research.	Ditto
5 2008	Annual report of field research Paper suitable for publication: "Synthesis of field research related to monitoring and evaluation in the CRE."	Data to feed the adaptive management system designed to aid decision-makers regarding habitat restoration projects
6 2009	Annual report of field research	Method to assess the success of habitat restoration efforts at the ecosystem level in the CRE. Methods, information, and recommendations for restoration decision-makers

Year	Deliverables	Management Application
7 2010	Annual report synthesizing seven years of research. Paper suitable for publication: "Columbia River estuary adaptive management restoration and research program: 7-year review and recommendations."	Proven methods for M&E of habitat restoration projects and program effectiveness.

G. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

This study would be led by Pacific Northwest National Laboratory (PNNL) and performed in collaboration with the NOAA Fisheries (NOAA), the Columbia River Estuary Study Taskforce (CREST), the Columbia Land Trust (CLT), and the University of Washington (UW). PNNL has nationally recognized expertise in coastal ecosystem monitoring and restoration. NMFS/Northwest Science Center is the leading research agency studying salmon ecology in the Columbia River Estuary, among many other locales. CREST is a council of local governments based in Astoria, Oregon that is heavily involved in monitoring and restoration in the CRE. CLT is heavily involved in the protection and restoration of CRE habitats. UW's Columbia Basin Research Center is at the leading edge in environmental statistics.

H. LIST OF KEY PERSONNEL

Role	Name	Organization
Principal Investigator	Ron Thom	PNNL
Co-Principal Investigator	Curtis Roegner	NOAA
Project Manager	Gary Johnson	PNNL
Restoration Ecologist	Heida Diefenderfer	PNNL
Wetlands Scientist	Allan Whiting	CREST
Fisheries Biologist	Earl Dawley	Retired-NOAA
Fisheries Biologist	Blaine Ebberts	COE
Statistician	John Skalski	UW

I. TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred in the form of written and oral research reports and scientific publications. Each year a presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review. A draft annual report will be provided to the COE by February 28 following each study-year, and after appropriate review final reports will be completed in a timely manner each year. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia.

As mentioned above under Deliverables, the proposed work will generate five articles submitted to the COE and suitable for peer-reviewed scientific journals: 1) "A review of cumulative effects research methods in ecological restoration;" 2) "Cumulative effects assessment strategy and adaptive management plan for the Columbia River estuary;" 3) "Techniques for monitoring restoration projects in the Columbia River estuary;" 4) "Synthesis of field research related to monitoring and evaluation in the CRE;" and 5) "Columbia River estuary adaptive management restoration and research program: 6-year review and recommendations." In addition, a Field Research Report series may be initiated in Year 3, to continue

through Year 6. The field report series would provide an opportunity for collaborators at various agencies and other entities to analyze the results of restoration project monitoring and directed research on cumulative effects and submit short papers to the COE; where warranted, these field reports would be submitted for peer-reviewed publication to disseminate information more widely. The field research reports would, in turn, be relied on in developing the synthesis paper in year 6, which would provide management recommendations for the estuary and related systems based on all information generated through this cumulative effects research program. Each year, the pertinent articles and research reports will be packaged in the annual reports described above in Deliverables and Schedule.

J. LIST OF REFERENCES

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IV. BUDGET

A detailed budget will be provided later under a separate cover.